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Pheromones in Insect-Pest Management

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Abstract
Pheromones are substances that insects create to influence the behaviour of conspecific individuals. These substances have a wide range of effects, and their names reflect the reactions they produce. Over the course of five decades, pheromone research has been driven by the need to use species-specific behavior-modifying compounds to control nuisance insects in agriculture, horticulture, forestry, stored products, and as disease-carrying insects. There are a large number of pheromones and other semiochemicals that are employed to protect plants and animals from insects as well as to keep track of insect population and presence. Pheromones are mostly long-chain unsaturated esters (primarily acetates), alcohols, and aldehydes structurally, and species specificity is determined by the identities of the various components of the pheromone blend and by their respective proportions in the mixture. Because pheromones are becoming more effective at low population densities and do not harm natural enemies, they are able to reduce insect populations over time in a way that is not possible with traditional insecticides. Pheromones and other semiochemicals can be used for sustainable area-wide management, which will increase food security for a growing population rather than intensifying the use of insecticides. Instead of killing the pest, they reduce the amount of male adults, their rate of reproduction, and their numbers, giving them an advantage over dangerous chemicals. Studies over the past 20 years have mostly concentrated on the discovery of novel sex pheromones, the analysis of sex pheromone perception mechanisms, and the incorporation of these new developments in pheromone research into IPM programmes.

Keywords: Pheromones, Semiochemicals, IPM, Allelochemicals, Allomones, Kairomones, Synomones, Antimony

Introduction
Nocturnal moths, soil-dwelling insects and social insects that live in confined nests make extensive use of odour cues. It has become obvious that substances or chemicals secreted from the insects play a role in both attracting insects and regulating their growth. A range of chemical compounds are involved in the interactions between different plant species and insects. The relationship between plant chemical stimuli and insect response is a form of chemical communication between these organisms. Semiochemicals are those substances that play a role in this communication. They are further divided into pheromones and allelochemicals.

Allelochemicals: These are interspecific signals, which are described as non-nutrient substances coming from an organism that influence the physiological state, behaviour, or ecological wellbeing of organisms of another species. They are categorised into the following groups:

a) **Allomones:** These chemical signals are beneficial to the emitter and not favourable to the receiver (e.g. defensive secretions).
b) **Kairomones:** Chemical signals that give an advantage to the receiver but not to releaser. (e.g. secretions that can be detected by a parasite or predator).
c) **Synomones:** These chemical signals are beneficial to both sender and receiver.
d) **Antimony**: Chemical signals in which neither is benefitted.

Pheromone: Pheromone comes from a Greek word meaning 'carrier excitation'. In 1959, German chemist, Adolf Butenandt, who identifies and isolates first insect pheromone from silk worm and the substance was a kind of alcohol that Butenandt christened bombykol, after moths named, *Bombyx mori*. German Biochemist, Peter Karlson and Entomologist, Martin Luscher (1959), who had been engaged in research on the chemical control of caste development in termites, proposed the term 'pheromone' to describe a chemical that an animal secretes or excretes that releases a specific reaction, for example, a definite behavior or developmental process in a member of the same species. These pheromones are divided into

a) Releasers, which induce an immediate behavioural change and
b) Primers, which initiate changes in development, such as sexual maturation, and so donot result in immediate behavioral changes. These are further classified as follows:

1. **Sex Pheromone:** A substance generally produced by females to attract males for mating.
2. **Aggregation pheromone**: A substance produced by one or both sexes and bringing both sexes together for feeding and reproduction.
3. **Alarm pheromone:** A substance produced by an insect to repel and disperse other insects in the area. E.g. the secretions produced by worker ants when they encounter a threatening situation.
4. **Parapheromone**: When a chemical not found in an animal has a pheromone like action. E.g. synthetic compound trimedlure, which is the best known attractant for the male Mediterranean fruit-fly, *Ceratitis capitata*.

Among the different types of pheromones, sex pheromones have gained importance in the pest management programme. Pheromones have the ability to involve in the metamorphosis, behavioural changes and sexual maturation. These natural properties of the pheromones have attracted the attention of several entomologists those who are involved in pest management programmes to exploit the pheromones in insect pest control. Pheromone chemistry ranges from the blends of aliphatic alcohols, aldehydes, esters and epoxides exploited by lepidopterous insects to alkenoic acids and aldehydes, branched alkanones, esters, monoterpene alcohols and aldehydes to a furanone employed by beetles.

Pheromones in pest management: Pheromones are crucial in the insect life cycle and are therefore excellent targets to interfere to obtain pest control. One the first attempts at controlling insects by pheromones was made against the gypsy moth, *Porthetria dispar*. Attempts were made to control the gypsy moth using traps baited with virgin females. Later crude extracts of female abdominal tips were used in monitoring traps. The compound was an alcohol named Gyptol. Subsequently disparlure was isolated and synthesized. Over the last 40 years, scientists have identified pheromones from over 1500 different species insects. Some of the important and frequently used pheromones are given table 1. Pheromones can used in different techniques in pest management programme as follows:

1. **Monitoring:** The use of sexual pheromones as lures in monitoring traps is now wide spread. Monitoring serves four functions: detection of outbreaks, establishment of emergence times of adult insects, distribution mapping and assessment of changes in abundance. Pheromone baited traps for monitoring pest population provide a highly sensitive means of detecting the insect pest with many advantages over conventional methods such as light traps and scouting programmes. Pheromone monitoring systems

can thus provide vital intelligence for the timing of insecticidal control measures. E.g. use of pheromone traps for cotton boll worm, tobacco caterpillar, pink boll worm etc.

2. **Mass trapping:** Population trapping by mass trapping becomes feasible with attractants that can outcompete sexual attractants. Most successful example are those of the bark beetle trapping programmes. In these insects, communication involves both aggregation and sexual pheromones and both males and females can be lured into traps. A powerful highly specific attractant should trap a sufficiently large number of target pest individuals to reduce its population below Economic Threshold Level. A modification of mass trapping is the lure and kill technique where instead of being trapped, the responding insects are exposed to a pesticide.
3. **Mating disruption:** This technique depends on blocking the communication channel between male female insects by flooding the medium with sexual pheromone. The exact way in which mating disruption is achieved may include masking of aerial trails by the persistent odour, formation of false trails from dispensers that as female of male mimics, greatly outnumbering the calling insects. The greatest success has been for the control of pink bollworm, *Pectinophora gossypiella* by using controlled release formulations of its female sex pheromone, a 1:1 mixture of (Z,E) and (Z,Z)- 7,11-hexadecadienyl acetate known gossyplure.

Aggregation pheromone: These pheromones induce aggregation of insects for protection, reproduction and feeding or combinations. This type of pheromones is mostly prevalent in coleopterans. e.g. Females of the bark beetle, *Dendroctonus frontalis* and males of phloem beetle, *Ips confusus*. These insect species produces a aggregation pheromone, frontalin (*Dendroctonus*) and ipsenol (*Ips*) for their aggregation, mating and feeding purposes.

Inhibition of oviposition: Anti-oviposition pheromones are known to occur in various Lepidoptera and Diptera. They are also known as epideitic pheromones, in reference to their effects of reducing intraspecific competition. e.g. female cabbage white butterflies add an anti-oviposition pheromone to the eggs during egg-laying and inhibits egg-laying by conspecific females. Females of the fruit fly (*Rhagoletis cerasi*) mark the fruit around the oviposition puncture and leaving the trail, which contains a pheromone. This host making pheromone deters other females of the species from ovipositing on the same fruit. This type of pheromones can be used in the pest management programme to reduce attack by the insect pests.

Alarm pheromones: Aphid species uses this type of pheromone to stop feeding and disperse rapidly group of aphids. The component of the pheromone is (*E*)-β-farnesene. This type of pheromone has been used to mobilize feeding aphids and insecticide sprays and pathogens more easily target them. E.g. Glandular hairs on leaves of wild potato released (*E*)-β-farnesene compound, which repels the aphid *Myzus persicae.*

Use of toxic baits: The use of pheromones in this type of toxic bait is vary less through food attractants and parapheromones have been used extensively. e.g. Methyl eugenol, which is a component of many flower fragrances is strongly attractive to males of certain tephritid Diptera. The compound have been used in the bait impregnated with insecticides and has been successfully used in eradiation campaigns for the control of oriental fruit-fly, *Bactrocera dorsalis.*

Stimulo-deterrent methods: In this technique, chemical substances may involve deterring insects from colonizing certain plants and at the same time, attracting them to other areas, hence the term 'stimulo-deterrent'. E.g. strips of cotton planted early in the season and baited with grandlure, the synthetic pheromone of boll weevil. Weevils are then killed with insecticide before they can spread to the commercial, which fruits later.

Bioelectric methods: The use of electrostatically charged powders as carriers for insecticides and biologically active chemicals, which adhere to the insect cuticle by electrostatic forces

and can be used as slow-release substrates for pheromones. e.g. pest control can be achieved by attracting insects to bait sex pheromones, where they up an inoculums of slow acting pesticides or pathogen, which they then pass on to mates during the mating process.

Formulation for pheromones: Since pheromones are volatile in nature, slow release formulations have been developed so that an effective release is maintained over several days after application. Such pheromone formulations are commercially available for several crop pests. Generally, the formulations used for monitoring are in the form of rubber septa, polyethylenevials or polyvinyl chloride dispenser, whereas those for mating disruption purposes include plastic hollow fibres, plastic laminate flakes, polyethylene tube dispenser, bag dispensers, etc. Some formulations are also available as emulsifiable concentrate or as polymeric aerosol. The microencapsulated formulation is used in aqueous suspension and can be sprayed by conventional applicators, but the fibre and flake formulation require an adhesive to ensure that they stick to foliage. Polyethylene tubes have to be applied by hand individually.

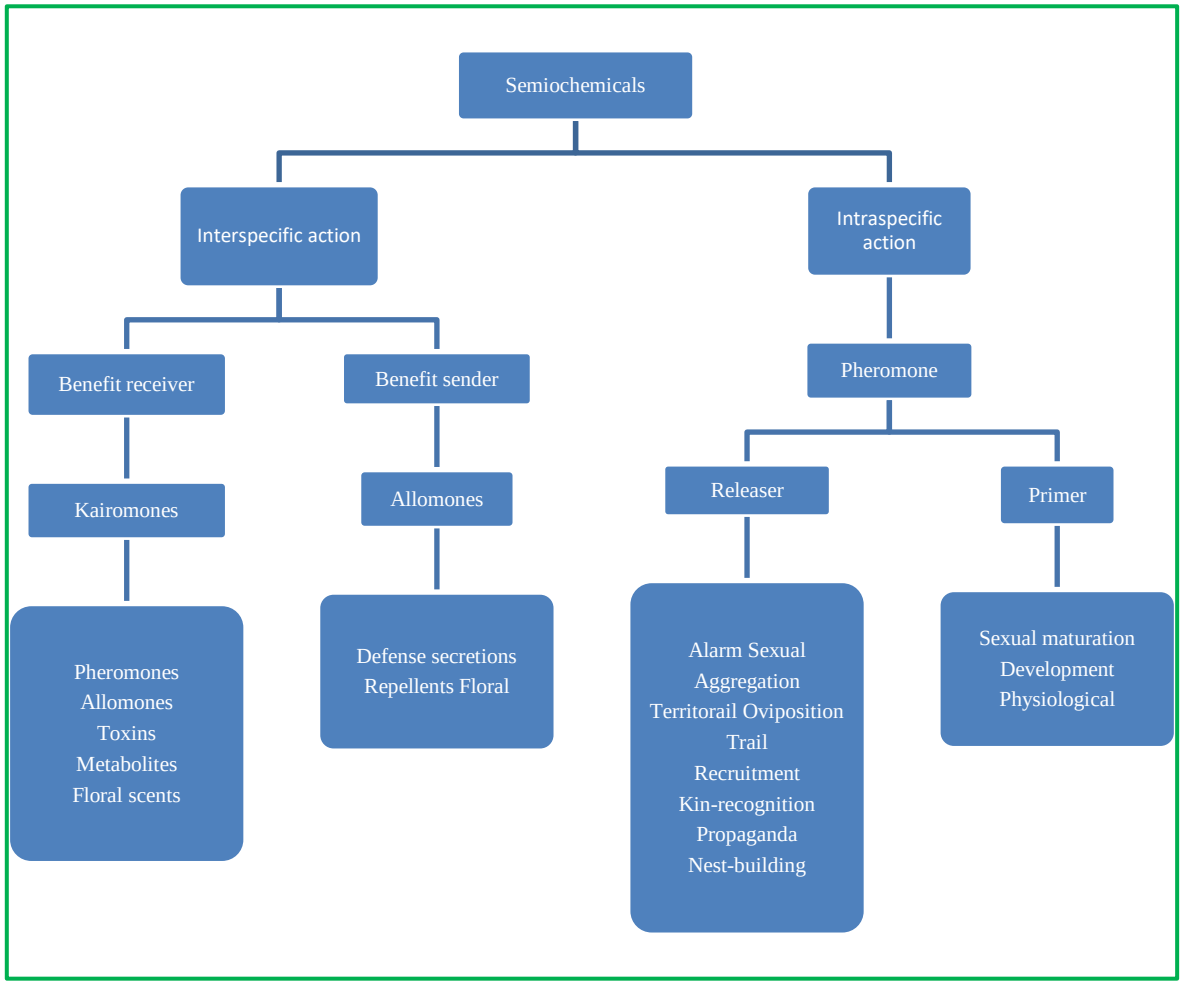

Fig.1 Categories semiochemicals examples (Reference: from Howse *et al*, 1998)

Advantages: Pheromones can used in integrated control along with many other methods.

1. Pheromone monitoring traps cheap to produce and transport and are highly selective.
2. Its compatibility with biological control and it is to be hoped that it will herald a new era in which the use of chemical pesticides will decline.
3. Pheromone monitoring traps are involved in detection, destiny estimation, forewarning of insect-pests and timing of pesticide application.
4. It is not leaving any toxic residues, hence these are environmentally safe.

Disadvantages

1. It is effective against a single pest or a closely related group of insects
2. Pheromones donot not provide immediate control of pests.
3. The chemical substances are not stable and photodegradable.
4. It has to be applied on an area wide basis in order to achieve desired results.
5. Lack of proper delivery system of pheromones in the field.

Table 1. Pheromones of some important insect pests:

S. No.	Common Name	Insect Species	Pheromone
1	Rice Stem Borer	*Chilo suppressalis*	(Z)- 9- hexadecenal (Z)- 13-ctadecenal
2	Yellow Stem Borer	*Scipophaga incertulas*	(Z)-11-hexadecenal (Z)-9-hexadecenal (3:1)
3	Gypsy Moth	*Porthetria dispar*	10-acetoxy-cis-7-hexa-decnol (Gyptol)
4	Tobacco caterpillar	*Spodoptera litura*	(Z,Z)- 9-11- tetradecadienyl acetate (Z,Z)-9, 12- tetradecadienyl acetate (10:1) (Spodolure)
5	American Bollworm	*Helicoverpa armigera*	(Z)-11-hexadecenal (Z)- 9- hexadecenal (97:3) (Helilure)
6	Brinjal Fruit and Shoot Borer	*Leucinodes orbonalis*	(E)-11-hexadecenyl acetate
7	Pink Boll worm	*Pectinophora gossypiella*	(Z, E)-7-11-hexadecadien- 1-ol acetate (Z, Z)-7-11-hexadecadien- 1-ol acetate (1:1) (Gossyplure)

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